CSS Long Term Control Plan Update

Hydrologic and Hydraulic Modeling Plan

City of Alexandria
Department of Transportation and Environmental Services

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GREELEY AND HANSEN

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Executive Summary

The City of Alexandria's hydrologic and hydraulic combined sewer system (CSS) model has been developed, updated, and maintained for over 15 years. Most recently, this comprehensive model has been coordinated with Alexandria Renew Enterprises (AlexRenew) and Fairfax County to incorporate both the City's CSS model and AlexRenew's interceptor model to provide a unified model for the entire collection system. This allows for a more comprehensive understanding of the current conditions of the system as well as to evaluate future needs.

The model has been calibrated against multiple years for flow meter data at each of the City's combined sewer overflows (CSOs) as well as many points throughout the separate part of the system. The calibration and subsequent recalibrations have been conducted at multiple points throughout the development and updates to the model. The most recent recalibration occurred in 2010 when the CSS model was combined with the interceptor model and updated to use the XPSWMM software.

This model will be used to evaluate the impact that various CSO controls will have on the system during the alternatives analysis portion of the City's Long Term Control Plan Update (LTCPU). Each alternative will be built into the model separately and will be modeled using the rainfall from the year 1984 as defined in the *Typical Year Selection Technical Memorandum* dated September 2014. The results of these model runs will be used to size and implements CSO controls appropriately.

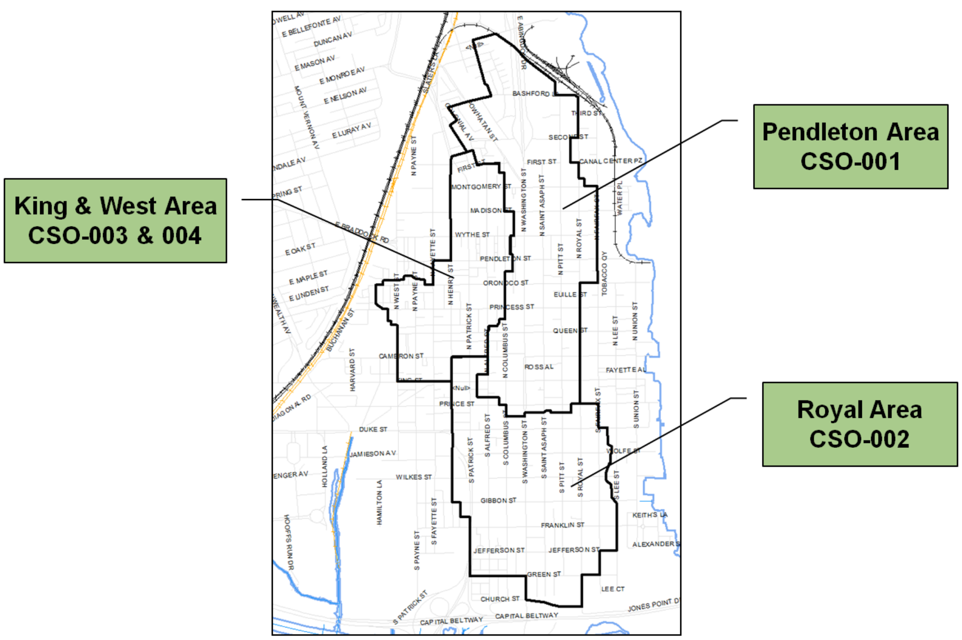
Section 1 Introduction

The City of Alexandria has developed a comprehensive hydrologic and hydraulic model of its sanitary and combined sewer system. The model was originally developed in the early 1990's, called the Sewer Overflow Model (SOM), and only included the combined sewer system (CSS) and combined sewer overflows (CSO). This model was used until 1996 when the City upgraded the model of the CSS to the more robust EPA SWMM 4.4H model. This DOS-based software was used to report duration and volume of overflows in the City's Annual Reports to the Virginia Department of Environmental Quality. In 2010 the City further upgraded the model to incorporate the interceptor model that had been developed by Alexandria Renew Enterprises (AlexRenew). The interceptor model is a hydrologic and hydraulic model developed by AlexRenew to model the interceptor sewers in the service area to have a better understanding of the way the system currently operates and for future planning considerations. This latest version uses the XPSWMM software and is able to simulate the hydrology and hydraulics throughout the entire City and results in a more dynamic and representative model.

The model consists of two major pieces: the interceptor system (maintained and calibrated by Alexandria Renew Enterprises) and the CSS (maintained and calibrated by the City of Alexandria). The CSS portion of the model is made up of three distinct areas corresponding to the CSO areas as shown in Figure 1-1.

Figure 1-1

Combined Sewer System Area

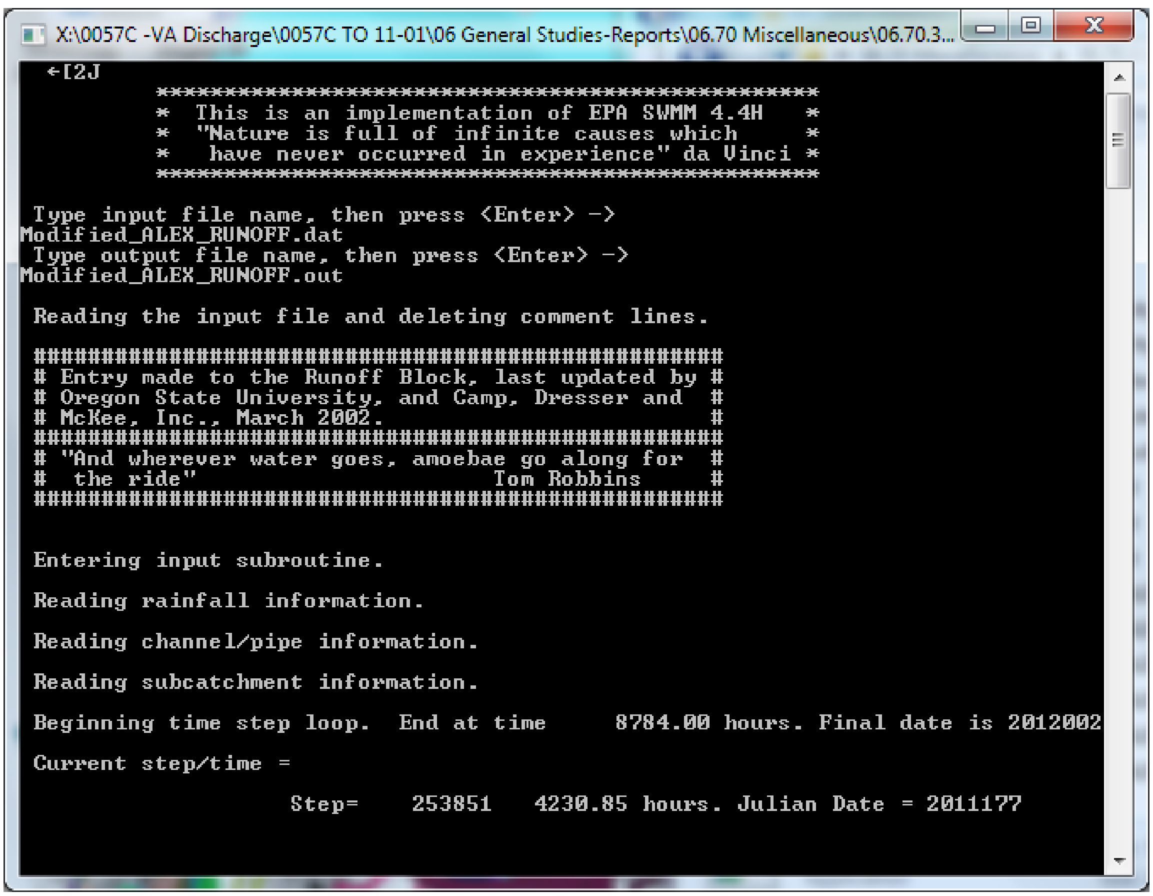


Section 2 XPSWMM Model

2.1 History

The previous EPA SWMM 4.4H model was developed and calibrated using flow metering data collected at each of the City's CSOs between 2002 and 2004. This DOS-based model shown in Figure 2-1 was only a model of the CSS and did not include the separate system or interceptor model. While this model did not include every sewer within the CSS it did contain the major trunk sewers and inflows so that the resulting overflows could be modeled accurately. The interceptor model was owned, maintained, and calibrated by AlexRenew, such that in order for the model to be run or calibrated, both entities (AlexRenew and the City) had to run their individual models. The results of the interceptor model would be used as the boundary conditions for the CSS model. While this worked and provided accurate results, the process was cumbersome.

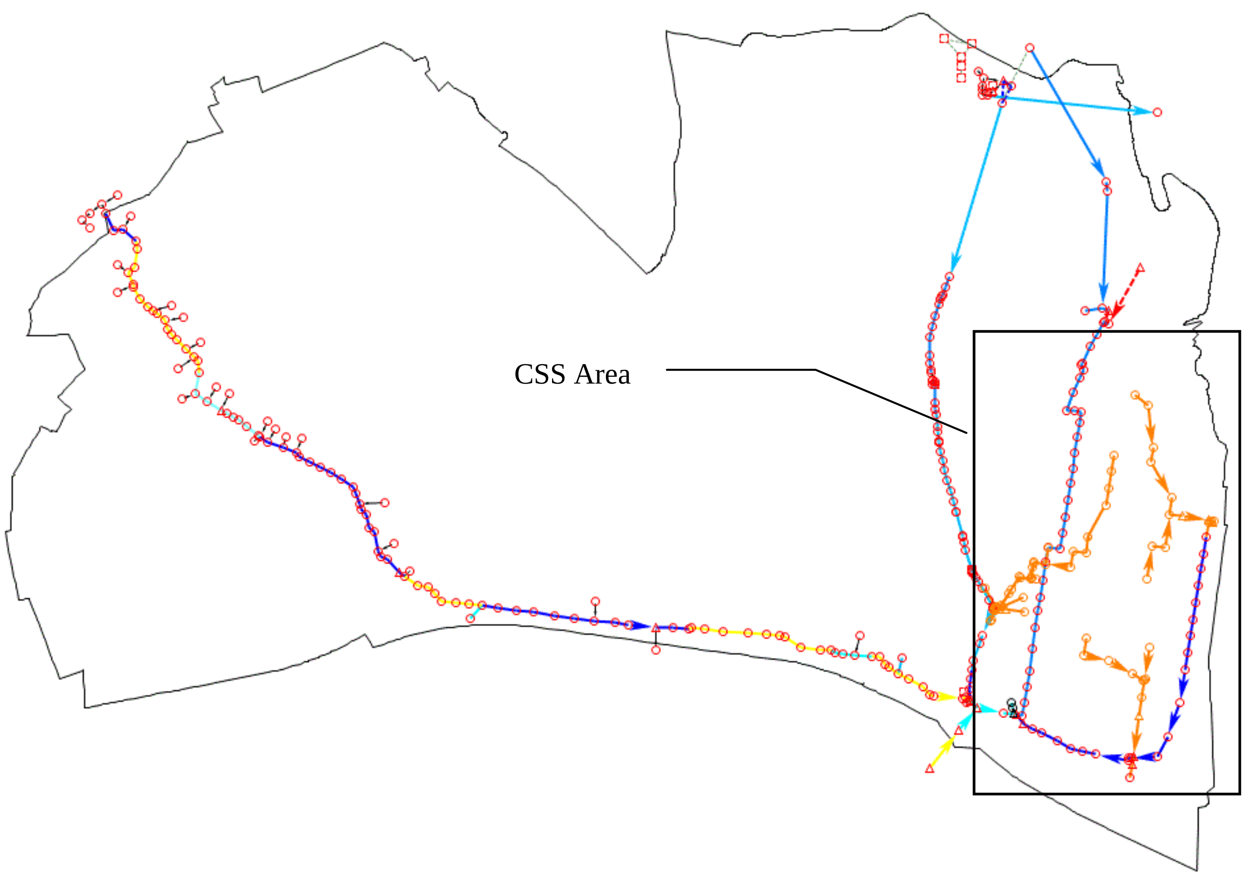
Figure 2-1
EPA SWMM 4.4H Model



In 2010, AlexRenew, the City, and Fairfax County entered into a partnership to create one unified model. This model would incorporate both the interceptor model as well as the CSS model to provide hydrologic and hydraulic results for both systems. In order for the integration to take place, the City upgraded their model to a proprietary version of EPA SWMM, called XPSWMM. This model provides a more visual user interface as well as additional pre- and post-processing tools. During the upgrade process all previous metering data including more recent metering data collected between 2007 and 2010 at each of the CSOs was used to recalibrate the flows entering and leaving the CSS.

The new XPSWMM model shown in Figure 2-2 integrates both the AlexRenew interceptor model and the City's CSS model into a single unified model. This model is more visual, dynamic, and more functional from a user's standpoint. It also allows for more refinement to the model which allows for better calibration and a better understand of how the system works as a whole.

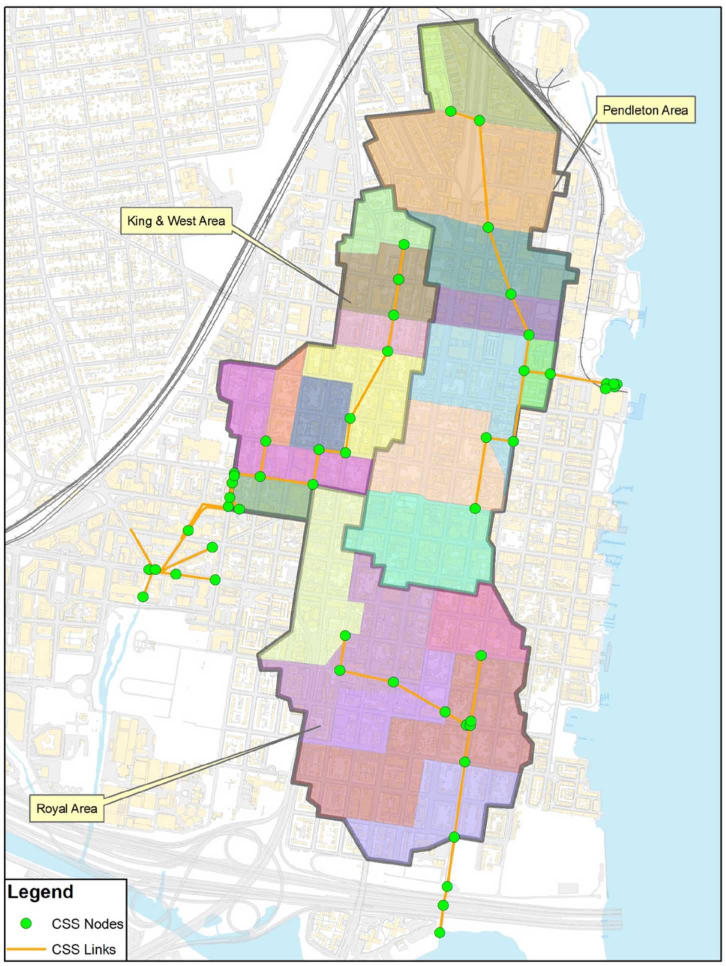
Figure 2-2
XPSWMM Model



2.2 Model Description

Each of the circles in Figure 2-2 represents a node in the model. Nodes are used to add flow or remove flow from the model. For example Figure 2-3 shows the nodes and links that are specific to the CSS. Each node represents two types of flow from the corresponding areas shown: 1) the sanitary flows from each of the buildings in the colored areas also referred to as the dry weather flow; and 2) the runoff entering the system from each of the colored areas also referred to as wet weather flow.

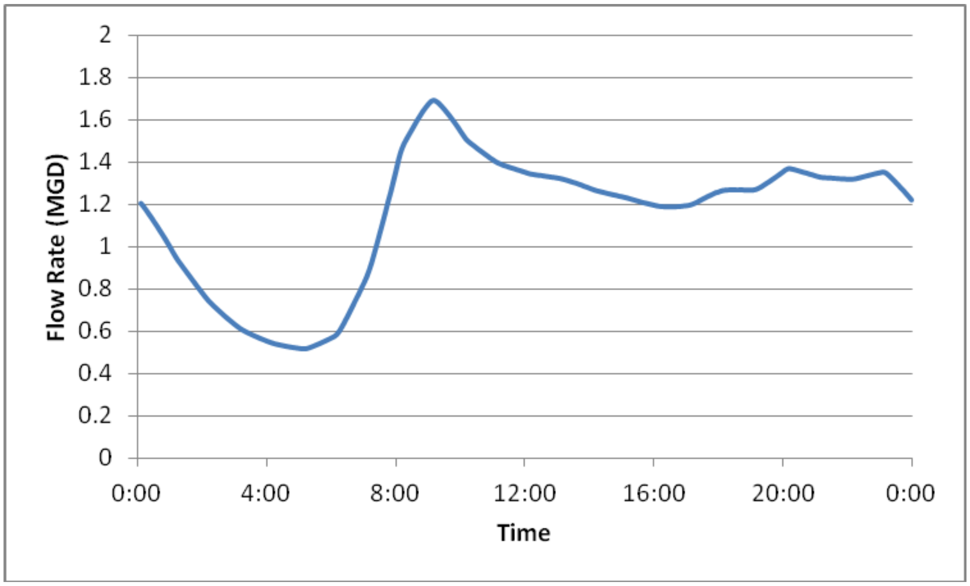
Figure 2-3
CSS Node Areas



The dry weather flow is determined by installing flow meters and measuring the flows in the system during dry weather. The resulting hydrograph produces a diurnal curve in which flows are lowest in the middle of the night, peak when people are waking up in the morning, flow decreases throughout the day while people are at work, and then there is a peak again in the evening when most people arrive at home.

For the most part each node in the model is assigned a diurnal curve with a similar shape but differing flow rates. A typical diurnal curve is shown in Figure 2-4.

Figure 2-4
Typical Diurnal Curve



Wet weather flows are calculated by subtracting the diurnal curve from the measured flows during wet weather events. At each node the diurnal curve can be manually entered into a table since it is assumed that they will not change significantly and will be used throughout the model simulation. Wet weather flows must be calculated by the modeling software using various parameters; within the CSS these parameters calculate the direct runoff of each area into the system. Specific to this model the parameters used to calculate the runoff into the CSS are: node area (acres), land use (% impervious), node area width (feet), and node area slope (ft/ft).

- Node Area (acres) – this parameter defines the area for which rainfall will be directed to a node. It is represented by the colored areas in Figure 2-3.
- Land Use (% impervious) – this represents the percentage of the node area that is covered with impervious surfaces (i.e., roads, sidewalks, buildings, etc.). This is important because most of the rainfall that lands on impervious surfaces makes its way into the system, while a smaller fraction of rainfall that lands on pervious surfaces makes its way into the system.
- Node Area Width (feet) – this is an estimate of how wide the node area is; node areas are assumed to be rectangular for modeling simplicity. The wider the area is, the shorter the length, and therefore the sooner the runoff enters the system. The skinnier the area is, the longer the length, and therefore the longer it takes for runoff to enter the system.
- Node Area Slope (ft/ft) – this is an estimate of the slope of the node area. The steeper the area is, the faster the runoff enters the system.

Initially estimates for all four of these parameters are made based on actual conditions. Through the model calibration these parameters are then individually adjusted to try to have the model output match the meter data that was collected. Generally, node area does not change and the other three parameters are adjusted within reason. A brief overview of the node characteristics are presented in Table 2-1.

Table 2-1
Node Characteristics

	# of Nodes	# of Links	# of Catchment Areas	Average Catchment Area Size (acres)
Pendleton Area	15	14	9	25.51
Royal Area	13	12	6	32.39
King & West Area	24	23	8	14.90

Once the flows enter the system at the nodes they are conveyed through links to other nodes. These links also have parameters associated with them that effect how much and how quickly flow can get through the system. More specifically, these parameters are:

- Pipe Length (feet) – the length of the pipe from manhole to manhole or node to node.
- Pipe Diameter (feet) – the diameter of the pipe.
- Pipe Slope (ft/ft) – the slope the pipe has been laid.
- Pipe Roughness – Manning's coefficient of roughness. The higher the coefficient, the rougher the pipe is, adding more headloss and slowing down the flow.

Typically during calibration these parameters are based on existing conditions and are not modified. When other options have been exhausted, modifying the pipe roughness slightly can help to achieve an acceptable calibration.

During the transition from the old EPA SWMM 4.4H DOS-based model to the new XPSWMM model, the model structure, settings, and calibrations were revisited. All data within the model was rechecked against design and as-built data as well as field inspections. Additionally, all flow metering data collected between 2002 and 2010 was used to perform a recalibration on all outfalls. This recalibration resulted in minor changes to the model and allowed for a more accurate representation of the CSS and interceptor system.

2.3 Calibration

When the model was upgraded to XPSWMM in 2010, all four outfalls were recalibrated to ensure that the model achieves an accurate representation of the system. Each CSO regulator structure was calibrated individually because flow monitoring was not conducted concurrently at each of the CSO outfalls. The calibration consisted of comparing the meter data to the model output and adjusting the time of concentration or roughness in the model as needed to achieve a reasonable agreement between the model output and the meter data. Figure 2-5 through Figure 2-8 show plots of the metered hydrograph versus the modeled hydrograph for each CSO.

Figure 2-5
CSO-001 Calibration Hydrographs

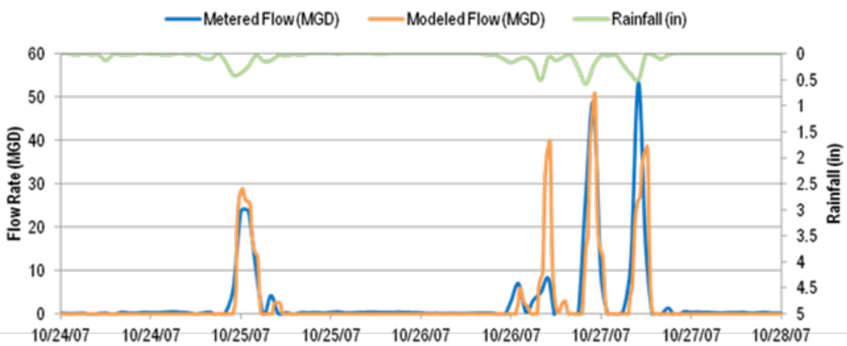


Figure 2-6
CSO-002 Calibration Hydrographs

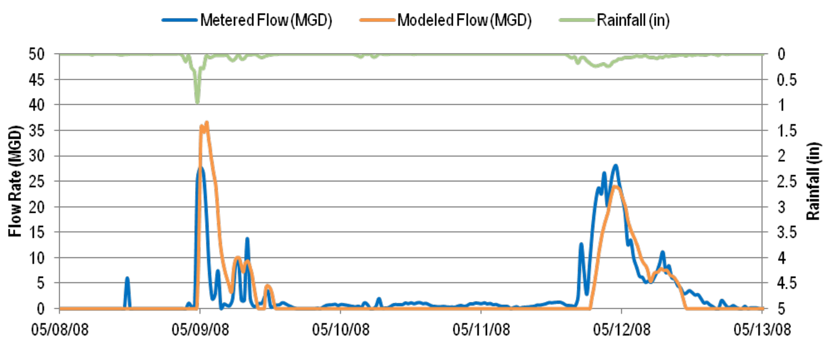


Figure 2-7
CSO-003 Calibration Hydrograph

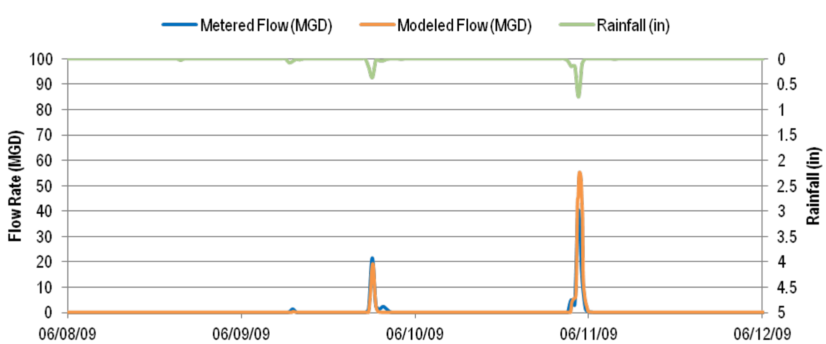


Figure 2-8
CSO-004 Calibration Hydrograph

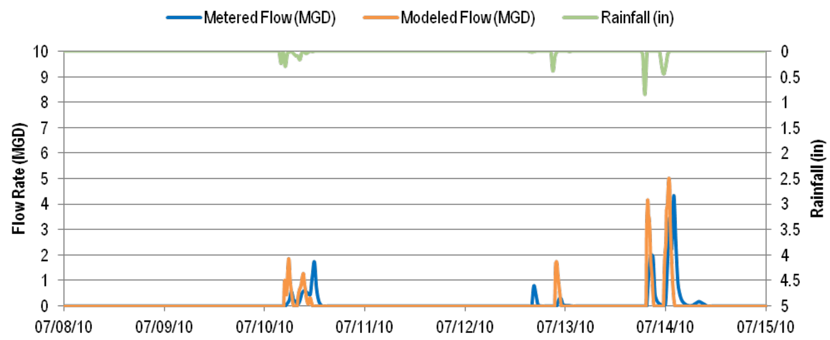


Figure 2-9 through Figure 2-12 show the relationship between the metered and the modeled event volumes. Ideally every event would fall on the red 1-to-1 line, meaning the modeled volume equals the metered volume. If the event point fall above the red line, then the model is under-representing that particular event; if the event point falls below the red line, then the model is over-representing that particular event. Adjustments were made to the model for each outfall until the calibration plots were acceptable.

Figure 2-9
CSO-001 1-to-1 Calibration Plots

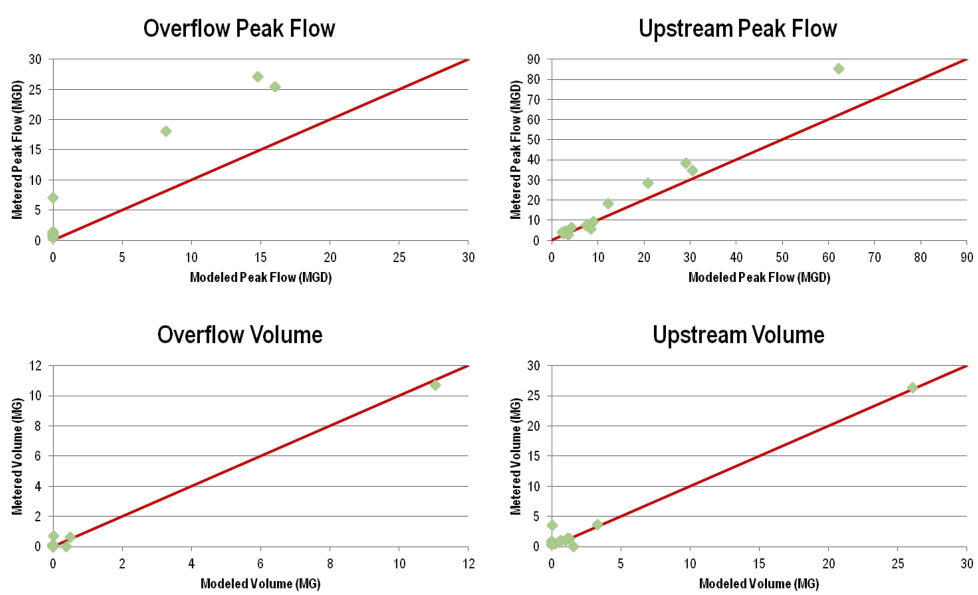


Figure 2-10
CSO-002 1-to-1 Calibration Plots

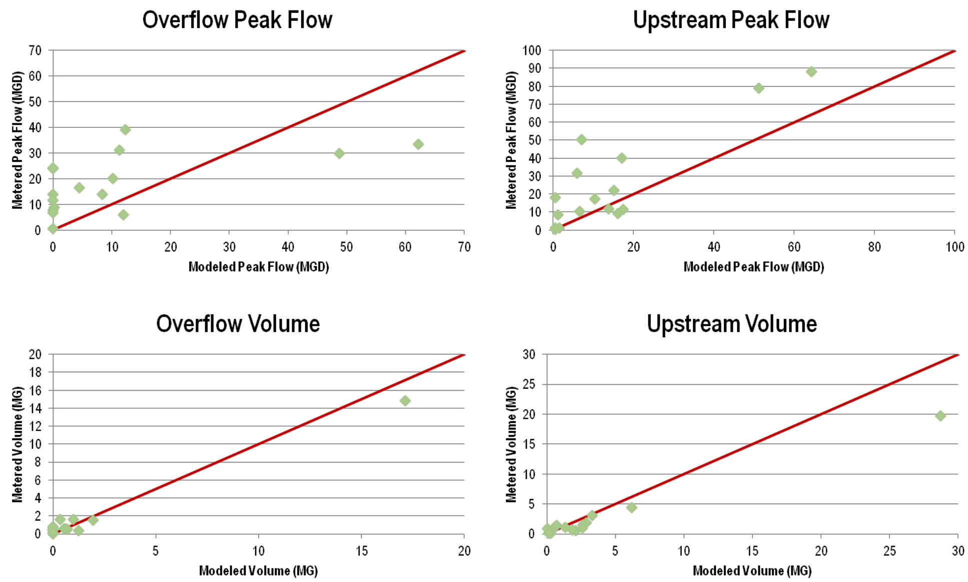


Figure 2-11
CSO-003 1-to-1 Calibration Plots

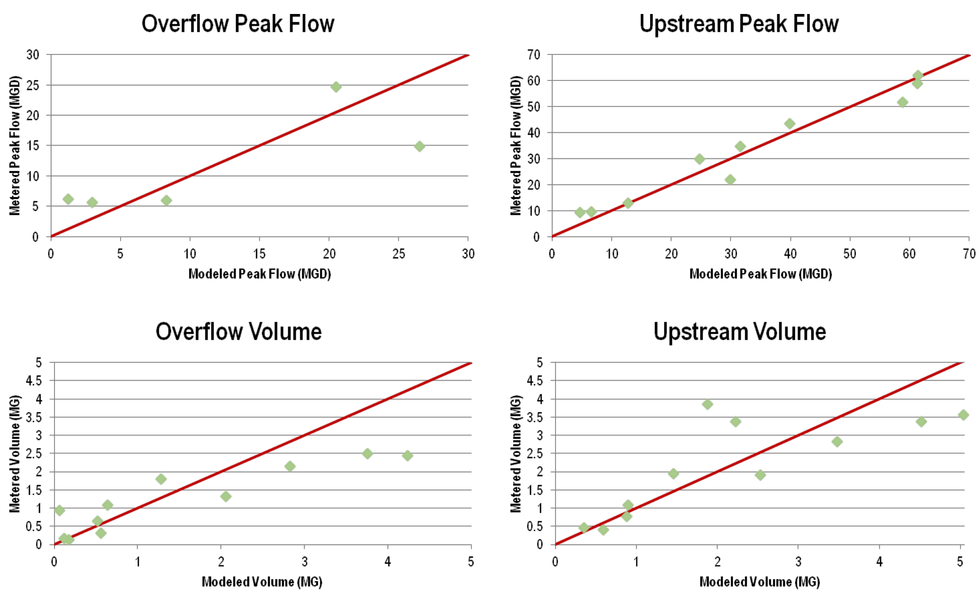
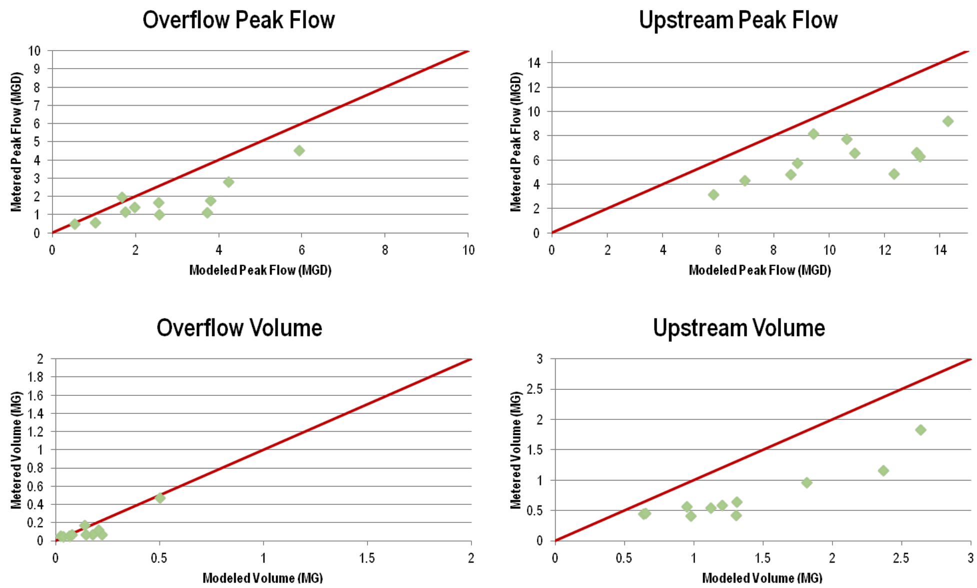


Figure 2-12
CSO-004 1-to-1 Calibration Plot



Section 3 CSO Controls Evaluation

3.1 Hydrology

The hydrologic and hydraulic model will be used to evaluate the system's response to wet weather conditions when implementing proposed CSO controls. The CSO controls will be evaluated against the typical hydrologic year in the City of Alexandria of 1984; this baseline model will not include any CSO controls and will be used to evaluate proposed CSO control alternative that are developed as part of the LTCPU. The wet weather in this year represents the typical annual wet weather as described in the *Typical Year Selection Technical Memorandum* dated September 2014. Precipitation data is available from Ronald Reagan National Airport in hourly intervals and will be used for all evaluations. This data will be used to represent rainfall uniform across the entire sewershed; while this is not typically the way rainfall occurs in the City, it will yield a very conservative estimate of flows within the system.

3.2 Flow Projections

All CSO controls will be evaluated under future flow conditions in Year 2040. The *Flow Projections Technical Memorandum* dated September 2014 presented these future flows. Areas currently being separated (or separated in the near-term) from the CSS as described in the *Combined Sewer System (CSS) Sewershed Changes Technical Memorandum* will have their flows removed from the CSS portion of the model and accounted for in the interceptor portion.

3.3 CSO Control Alternative Evaluation

The model will be used to simulate the effect each proposed CSO control technology would have once implemented within the system. The model results will be analyzed to estimate the effect of control technologies on CSO flow rates and volumes. Individual controls as well as combinations of CSO controls will be evaluated to in the *Alternatives Evaluation Technical Memoranda* as part of the LTCPU.

Greeley and Hansen LLC
5301 Shawnee Road
Alexandria, VA 22312
571-581-3000
www.greeley-hansen.com

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